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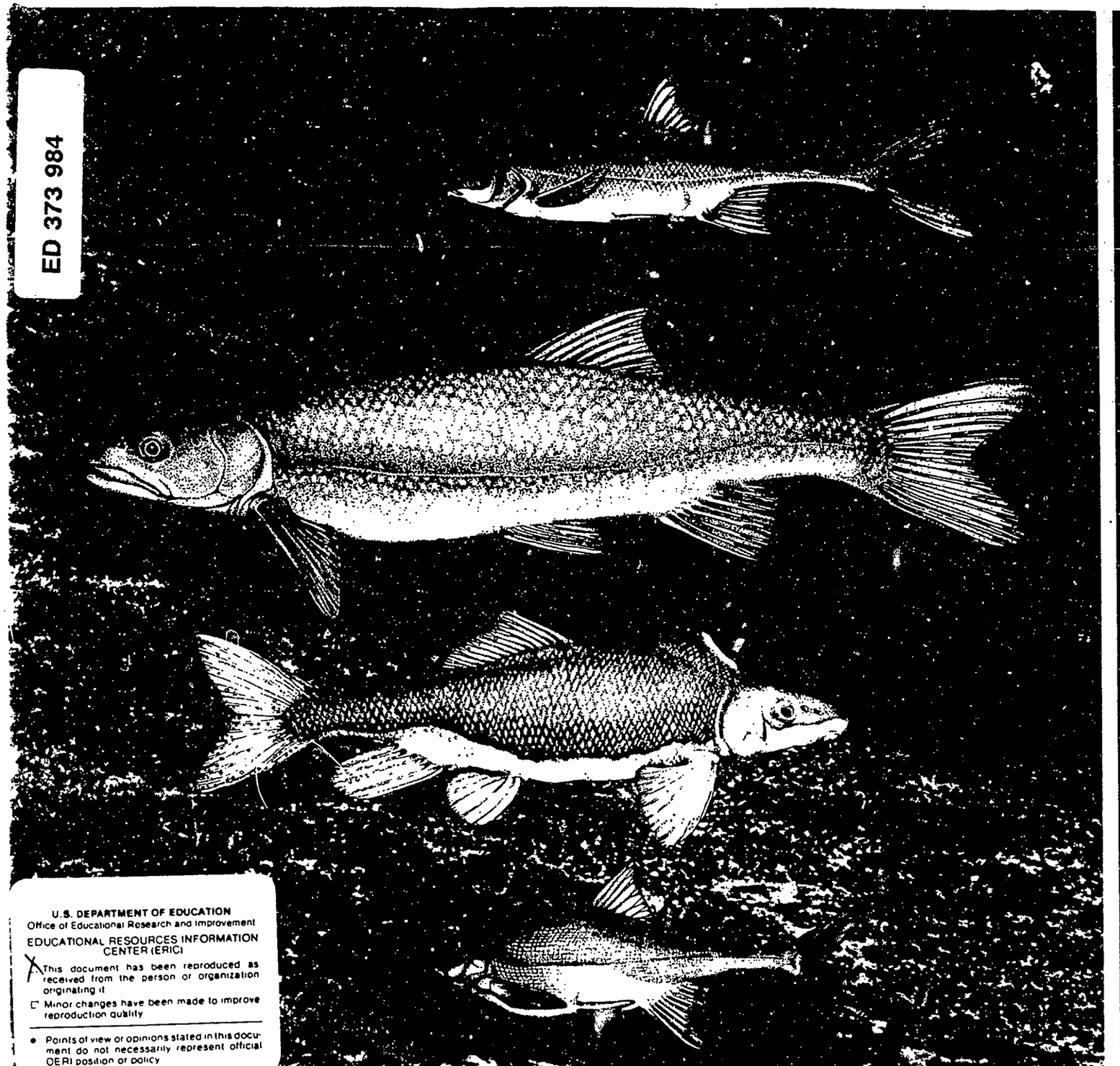
ABSTRACT

This activity guide is intended to increase student awareness and understanding about the Colorado River Basin. Each activity includes objectives, procedures, materials list, related activities, questions for students, and related information. The activities are varied to appeal to a wide range of learning styles and modalities and are interdisciplinary in design. The first chapter is an overview for teachers and the remaining chapters contain the activities: (1) "Wildlife Webs"; (2) "Big Basin Blues"; (3) "Rights and Wrongs"; (4) "Water in the Air"; (5) "Canyon Country Art"; (6) "Counting Water"; (7) "Ancient Waters"; (8) "Invisible Passengers"; and (9) "Habitat Hazards." (MKR)



RIVERS AT RISK

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RIVERS AT RISK

AN ACTIVITY BASED STUDY GUIDE FOR THE COLORADO RIVER BASIN

Produced By The United States Fish and Wildlife Service

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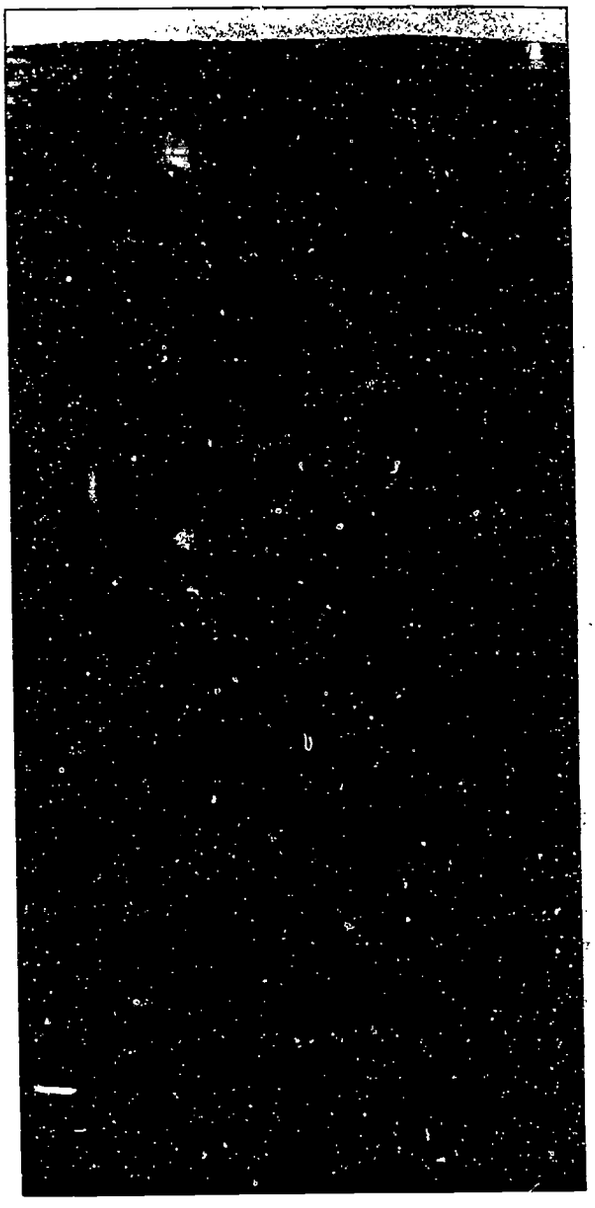


INTRODUCTION FOR TEACHERS

The activities in this booklet are intended to increase student awareness and understanding about the Colorado River Basin. They are written for teachers, with some materials to be reproduced for student use. These instructional activities are intentionally varied in order to insure an appeal to a wide range of learning styles and learning modalities. Art, field study, library research, simulated field trips, writing, oral reports, calculation and data gathering are among the approaches used.

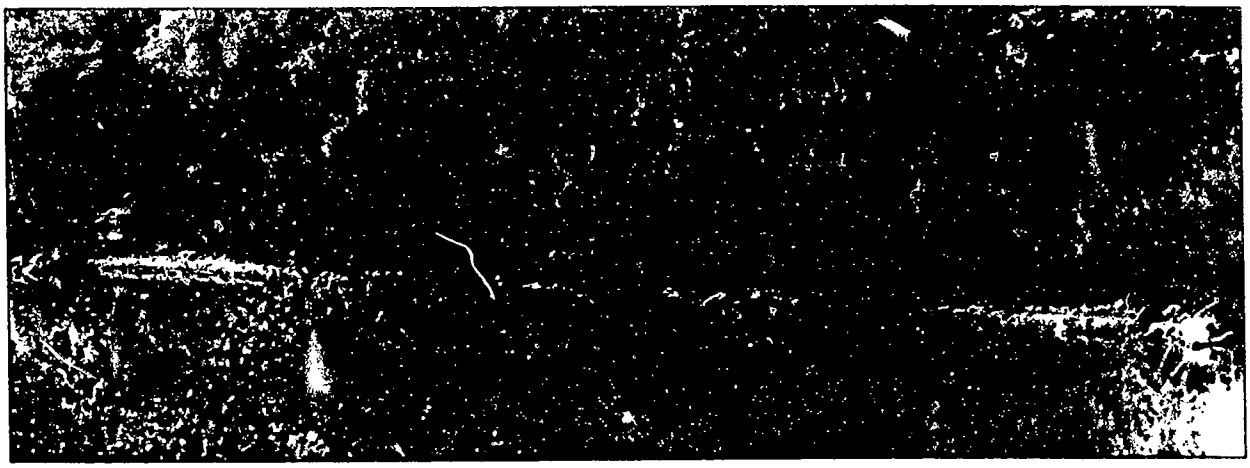
The activities are aimed at students from early primary to high school. As none of these materials is intended for the students to use directly, teachers may adapt them for younger children, and older youth. The main focus of the materials is the Colorado River Basin, yet the core ideas may be adapted to other parts of North America or the world.

The materials are transdisciplinary in design. This means that some activities may draw from concepts in multiple subject areas. For example, *Habitat Hazards* requires that the students make a model of the Colorado River Basin and display current and original ranges for four endangered fish species. This involves geography, art and biology. Varied skills are called upon as well; cooperation, communication and critical thinking are necessary for successful engagement with this activity.

Ideally, after experiencing these activities, students will transfer what they learn into actions in their own lives.

A VAST AND FRAGILE LAND

THE COLORADO RIVER BASIN: AN OVERVIEW FOR TEACHERS



UNIQUENESS OF THE RIVER SYSTEM

Few places on Earth have captured the imagination of people more than the vast expanses of the American Southwest. Our memories are filled with tall spires and stone monuments, wide sweeping plateaus and dense thickets crowding the banks of the rivers. Rivers once flowed ceaselessly from 14,000 foot peaks on the continental divide toward Mexico and the sea, 1400 miles away. The region is a geological wonderland.

Stone dwellings of ancient civilizations are scattered throughout the Colorado River and its tributaries. These ruins speak to the centuries in which humans and the river lived side by side before Europeans settled in North America. Carvings in the rock surfaces, called petroglyphs, show us that many of the animals we find today were common in the past. It is a land of contrasting people with dozens of indigenous tribal cultures living in the drainage of the river that dominates this land—the Colorado.

This has been a land of adventure and romance. In films and stories, the triumph and tragedies of westward expansion are often set in this vast, compelling environment. For nearly 500 years, explorers and settlers traveled across the surface of this region seeking cities of gold, routes to the Pacific, and, for some, homesites where they would try to wrest a living from the land. It was these early visitors who brought technologies that seemed innocent enough at first, but would change the face of the land forever.

Settlement was the first of the major activities of early immigrants to the Colorado River drainage. They settled and began to farm, raise livestock and to mine. In a short time, the effects of distant activities began to fuel changes throughout the entire nation. In the 1800s the dawning of the Industrial Era began. With it came rising population, established trails, wagon trains and eventually the railroad. Railroads opened up the wildlands of the west, bringing many more people to the region. This wave of settlement reshaped the land. For many settlers the only obstacle in the path of gaining a livelihood was access to water.

Then and now, water is the lifeblood of the west. The Colorado River drainage provides water today for 25 million people. Water is sought for crops, livestock, mining, recreation, municipal and industrial purposes, as well as for hydroelectric power generation. Also, and perhaps central to our exploration, the Colorado drainage is home for fish and other forms of wildlife.

The Colorado River drainage is a unique habitat. Its watershed drains a large portion of the the United States. The region is largely arid. Although there is low precipitation, heavy rains often fall in short periods of time. This causes

water levels in the river to rise and fall in dramatic fashion. The flow of the waters in the system varies from wide meandering stretches to narrow explosive cascades. During spring runoff, many rivers in the system are loaded with silt, a fine sediment that clouds the water.

In the higher reaches of the Colorado and its tributaries, water quality tends to be good to excellent. But as one travels downstream, there are many changes. Surprisingly, many of the changes in water quality have little to do with human activity. For example, many of the sedimentary rocks contain salts, metals and other elements that naturally enter into the waters. Each tributary has its own "suite" of naturally occurring chemicals that affect the water quality downstream. Yet there is little doubt that it is human activity that creates the major changes in water quality in the Basin.

DRIFTING TOWARD EXTINCTION

As abundant as life is in this region, there are many examples of species at risk. For this exploration, our focus will be on the plight of four species of fish indigenous to the Colorado River Basin. They are "indicator species" that reflect some of the changes taking place in the environment. Indicator species are those organisms that have specific requirements for survival. When indicator species are found, it is correct to assume that those conditions they require exist in the habitat. The occurrence of these species provides a way to quickly assess the health of the environment. The four species for this exploration are the razorback sucker, Colorado squawfish, bonytail and the humpback chub. Today all of these fish are listed as endangered species by the U.S. Fish and Wildlife Service. Why focus on these four fish as indicator species? Consider the following.

In the early days of mining, canaries used to be taken into coal mines to detect signs of gases that were dangerous to miners. If these gases were present, the canaries died but gave the miners enough time to escape. Individual species of plants and animals often exhibit similar sensitivity to changing conditions in an ecosystem. For a species to become threatened or extinct, changes must have occurred in their life support systems with which they are unable to cope.

A century ago these four fish were found throughout much of the Colorado River drainage. Now the favored habitat of each endangered fish is far more limited and their existence is at risk. What are the kinds of changes that have taken place in the Colorado river drainage system to bring this result? Fisheries specialists are conducting research and managing resources in efforts to discover answers and insure their survival. What are some of the things that are known about each of the fish that can extend human understanding of their requirements?

Note: For specific information about these fish, refer to the Endangered Fish Information Cards in the appendix.

Since these species are on the edge of extinction, they are considered indicators of environmental conditions that have changed from stability to conditions of threat. They are reference points as we explore the various conditions that have affected their ecosystem.

Basic to the study of ecosystems is the premise that all parts are connected—and important—to all other parts. Changes in one place ultimately affect other places. For a species to become endangered, there have to be significant changes in the conditions that support their livelihood. To understand the web of connections which can affect its survival it is important to examine *each* species and determine the conditions it needs to flourish.

Within an ecosystem each species has its *niche.* A niche is how an organism "makes its living"—how it eats, reproduces, grows and contributes to the whole of the living environment in which it is found. Taken together, the collection of niches in any ecosystem describes a larger system. The entire Earth can be viewed as a *single ecosystem.*

In recent years biologists and ecologists have emphasized the importance of seeing the world as a whole. There has even been a new term to frame their emerging interest—*biodiversity.* Biodiversity is an index of diversity and variety of living things in an ecosystem.

When we consider the role of each species in an ecosystem it is impossible to isolate one organ-

ism from another. Instead we must consider the system as a whole. The four fish that we are citing as indicator species are related to the other species in the system in ways that we know too little about. Should they continue their journey toward extinction, the biodiversity of the Basin would decrease and conditions would never be the same.

It is clear that we are witnessing a time in the history of the Earth when there is a severe loss in biological diversity. Many examples exist and one of the most commonly reported is the destruction of rainforests across the planet. Since all species in any ecosystem are interrelated and often interdependent, it is clear that the removal of a particular species might affect the entire system. The conditions that have brought the four species of fish to endangered status are really symptoms of threats to all parts of the ecosystem and the biodiversity it contains.

BIODIVERSITY IN THE COLORADO RIVER BASIN

Within ecosystems there are certain indicators that show how healthy an area is. One indicator is the diversity, or variety, of life that is found in an ecosystem. In the Colorado River Basin there is a wondrous diversity of interrelated life forms. A wide variety of plants, insects, fish, amphibians, mammals, reptiles and birds make up the list. It is important to remember that this condition did not emerge all at once. Biologists believe that such diversity and abundance in an ecosystem is a function of immense spans of time, leading to a combination of plants and animals in a dynamic, yet stable habitat. It is estimated that the Colorado drainage has been relatively stable for nearly 10 million years.

Although there is remarkable biodiversity in the Colorado River Basin, there is a surprising number of animals and plants that are severely at risk, including the four fish species we are emphasizing. There are scores of animal and plant species that are listed as endangered or threatened. A close look at any of the species that are at risk would provide an awareness of the many changes that have impacted the Colorado River Basin in the past hundred years. In some parts of the Basin stands of cottonwoods and willows, once common along the river banks, have nearly vanished. In the south, honey mesquite thickets have been clearcut on both sides of the river, reducing the habitat of many birds. Riparian habitats, the highly vegetated zones alongside the waterways, attract humans, wildlife and domestic livestock, all of which trample, disturb, or destroy the plants.

Other endangered and threatened species in the basin include bald eagles, peregrine falcons, white pelicans, whooping cranes and greater sandhill cranes. Although they were once found in the area, the gray wolf, grizzly bear and Canada lynx are no longer found in the basin. River otters, once common to this area, appear to have been lost. Biologists in various parts of the basin have begun to reintroduce them.

NOTE: It is important to remember that some species are listed on State lists as endangered and threatened and do not appear on the U.S. Fish and Wildlife Service listings.

Exotic species, those introduced from other habitats, include the tamarisk or saltcedar tree and over 50 species of non-native fishes such as salmonid trout, catfish, northern pike, red shiners and striped bass. Pheasants, starlings, rock-dove and English sparrows are a few of the exotic birds. Mammals such as burros, horses, and rodents have also been introduced.

When habitat loss is combined with the pressure created by the addition of exotic species, changes accelerate and become so widespread that they may become irreversible. The four fish species we have chosen to highlight as the players in this educational exploration represent a significant potential loss in biodiversity. Because they are near extinction and they have been part of the ecosystem of the Colorado River drainage for such a long period of time, the effects of their loss cannot be predicted with confidence. What are the things that can be done? What can people do to reverse the conditions that brought these four fish as well as other plants and animals to the edge of extinction? Before addressing these questions it is important to get a sense of the conditions that have changed the habitat in the past and in the present.

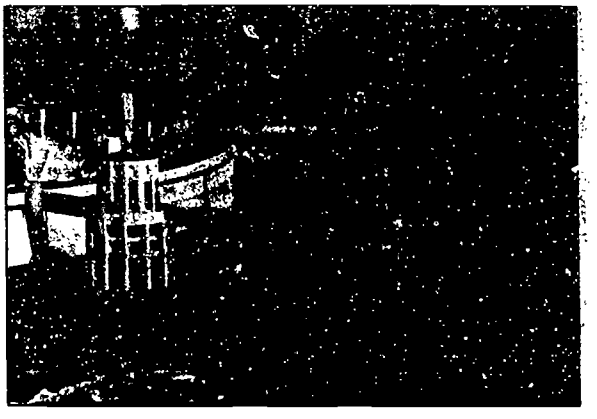
DAMS AND HABITAT

The drainage of the Colorado River Basin was once a web of free flowing rivers, creating a wide array of different habitats. These habitats supported an equally wide array of animal and plant life. Local weather events produced flash floods and often resulted in catastrophic conditions. In the longer view, the climate of the region and the effect of temperature and precipitation insured adequate water for the rivers of the system. The overall outcome was that the rivers flowed onward and nourished life along their shores.

It was under such conditions that living things established their roles within the ecosystems. The changes that took place daily and seasonally were well within the tolerance limits of the thriving organisms. The four fishes—razorback sucker, Colorado squawfish, bonytail and humpback chub—were well established in their niches. This is not to say that there weren't conditions that may have threatened their well being. In any ecosystem, there are unexpected and often destructive conditions. Yet healthy ecosystems, those with adequate biodiversity, have enough resilience to cope with occasional catastrophic events. Then came the dams.

To create a more predictable and reliable source of water for agriculture and to prevent the rivers from flooding homes and property, dams were proposed and built. The first was Boulder Canyon Dam started in 1929 and completed in 1935. It was built across the Colorado River near Las Vegas, Nevada. It is now known as Hoover Dam. In the years since this epic event, more than 20 other dams have been built in the Colorado River drainage. Some, like Hoover Dam, are capable of generating hydroelectric power.

On both sides of each dam—upstream and downstream—massive changes in habitat took place and were significant for the fish and other aquatic life found in and alongside the rivers of the Colorado Basin. Changes in temperature, salinity, silt load, rates of flow, magnitude of flow and the times of day or season that the flow took place all contributed to the familiar array of conditions experienced by the original inhabitants of the riparian ecosystems. It must be remembered that the endangered fish we are using as our key indicators normally migrate significant distances for breeding and spawning. Now dams block these natural migration routes.



POLLUTION

As water became more available and controlled, the population of the Basin grew. With the increased human activity, pollution, in its many forms, began to create short and long term environmental effects in the Basin.

Salinity or pollution by various salt compounds, originates from many sources. A significant amount comes from the rivers' waters flowing over rock deposits that yield a variety of salts. Human activities, such as irrigation, tend to dissolve salts and concentrate them in the soil. High levels of salts greatly reduce crop production in irrigated lands.

Heavy metals coming from mining activities include lead, copper, zinc, cadmium, sodium, sulfates, iron, manganese and strontium. These metals can cause damage to certain organisms. Shale and carbonates often are washed into the river systems following coal mining.

Acid precipitation results from sulfur dioxide and nitrogen oxide dissolving into water in the air. They are pollutants generally produced from automobile emissions, electrical generating plants, industries and smelters that burn coal and other fossil fuels. Both rain and snow may contain higher acid levels. Acid precipitation is causing lakes and streams in the high altitude environments of the system to shift toward a more acidic composition. The acidic waters are toxic to many forms of aquatic life.

Thermal pollution is found in the waters behind dams and at the places where the dams release water. As dams fill up, the impounded waters spread to form a lake. The lake increases the surface area of the water and through the sun's action, the water heats up. However the water at the bottom of the impounded lake is shielded from the sun's rays and becomes colder. When water is released from many dams it is commonly drawn from the bottom. This results in a kind of "thermal" pollution that is characterized by extremely cold water. This affects the downstream organisms in the water. For example, most native fishes have been replaced by introduced species such as trout which are adapted to cold water.

THE FINAL ANALYSIS

Returning to the indicator fish, there is no question that the habitat for these endangered species has been altered. Human attempts to change and control the river altered those natural patterns forever. Now these fish face multiple and perhaps insurmountable threats, including dams, decreased water flow, changed water temperature, interrupted flow of sand and silt, lower turbidity, introduction of exotic species, pollution and channelization (the scouring out of river channels by fast moving water).

For each of these four endangered fish species, only relatively short stretches and pockets of the river system are left that provide favorable habitat. Although the four species lived in the river system for as long as 4 million years it has taken only 60 years to bring them to the brink of extinction. Gone for all of them is access to their former migration routes. These once open routes are forever blocked by a system of dams.

THE WAY BACK

While it may seem that we have emphasized the habitat requirements of only four species of fish, we must remember that we are in fact looking at an entire ecosystem that has been altered. The four endangered species are indicators of injury to the entire system that contains them. We have no way of knowing how many species not as conspicuous as these fish are being pushed beyond the edge of extinction. Habitat destruction is the single most significant threat to all of life. We humans and our fragile habitat are in the equation as well.

As we look at the entire Colorado River system, it is clear that the original habitat will never be restored. There is too much of an investment in the infrastructure of civilization to rid the entire plateau of all human alterations. Besides, many human efforts have improved the quality of life for people and in some cases for other species. The reality of human involvement with natural systems is a basic fact of contemporary life. Sustaining human activity in the natural world is a question of balancing use, conservation and preservation. We cannot ignore economics and sustainability in an attempt to restore the pristine ecosystem of the Colorado River drainage. But we can attempt to restore the balance where possible. Finally, we must answer these questions: Can we manage what remains of the original ecosystem, and the changes we have made, so as to insure an adequate habitat for the four endangered fish species chosen for this exploration? By studying these four creatures can we learn how to balance the conditions that would assure survival for other endangered species? Are we willing to pay the price to guarantee that we share the planet responsibly with the species that still remain?

It is far too soon to answer these questions with certainty, but it is not too soon to try. Many dedicated professionals are well under way in attempts to accomplish what needs to be done. Data gathering, research, experimentation, and education are all simultaneously being conducted. Laws have been passed in an attempt to help. Public support for these laws is critical. A kind of ecosystem of information is being created where the results of ongoing studies and efforts are being woven into a tapestry of hope. There simply is no time to waste if these efforts are to succeed. The lines between legislation, research and application are difficult to separate. Action is being taken on what we now know and new information is simultaneously being drawn into the knowledge base. The following list is partial testimony to the efforts:

- ***Fish passages.*** Creating fish ladders and other passages around dams.

- ***Regulation of flow.*** Tailoring the release flow to species requirements.

- ***Law enforcement and Monitoring.*** Preventing human destruction of habitat and keeping legal efforts current.

- ***Education.*** Helping people understand the problems and their roles in them and expanding public knowledge about biodiversity.

- ***Continued research.*** Gathering the information base for action.

- ***Habitat restoration.*** Putting habitats back together.

- ***Hatchery programs.*** Breeding and stocking endangered fish.

- ***Cooperation between agencies.*** Communicating in positive ways.

- ***Information networks.*** Spreading the word.

CONCLUSION

This exploration develops an overview of some of the changes in ecosystems that affect the life within them. The primary emphasis has been the plight of four species of fish which are endangered. It is helpful to remember that they are, in fact, a metaphor for all life on the planet. Everywhere there are conditions, sometimes naturally occurring but mostly human caused, that threaten the balanced flow of life. The natural biodiversity of the planet is being placed at risk everywhere. The urgency with which many sectors of society now treat this problem is testimony to the widespread awareness of this fact. The problem is not just biological or ecological—it is economic as well. Habitat means *home for life*. When life is threatened anywhere, it is threatened everywhere. There are two lessons in this. First, losses within any ecosystem are ultimately losses to us all. Second, we each can take informed and appropriate actions to make a difference for life and the conditions that support it, now and in the future.

WILDLIFE WEBS

(GRADES 4 - 12)

WHAT WE WANT

Students will be able to identify and geographically locate various kinds of animal and plant life in the Colorado River basin.

HOW TO DO IT

Students make a list of animals and plants that they have actually seen in their travels around the Colorado River Basin. Then they locate on a map the places where they saw the animals and plants. Finally, they locate on the map any threatened and endangered species in and adjacent to the Colorado River Basin.

NOTE: Photocopy the Endangered and Threatened cards using colored paper. Photocopy and enlarge the Colorado River Basin Place Name Map found in the appendix.

USEFUL INFORMATION

Within ecosystems there are certain indicators that show how healthy an area is. One indicator is the diversity, or variety of life that is found in an ecosystem. A measure of that variety is called biodiversity. In the Colorado River Basin there is a wondrous diversity of interrelated life forms. A wide variety of plants, insects, fish, amphibians, mammals, reptiles, and birds make up the list.

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Some other endangered and threatened species in the basin include bald eagles, peregrine falcons, white pelicans, whooping cranes and greater sandhill cranes. Although they were once found in the area, the gray wolf, grizzly bear and Canada lynx are no longer found in the basin. River otters once common to this area appear to have been lost. Biologists in various parts of the basin have begun to reintroduce them.

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When habitat loss is combined with the pressures created by the addition of exotic species, changes accelerate and become so widespread that they may become irreversible.

WHAT WE NEED

Paper or 3x5 cards (one per student); approximately 50 feet of yarn; masking tape; scissors (one pair per group).

STEPS TO SUCCESS

1. Divide the students into groups of four to six. Ask each student to make a list of at least four animals or plants they have seen in the Colorado River Basin. Have them try to remember the geographic location where they saw these life forms.
2. Ask them to discuss the animals or plants with the other members of their group. Ask them to emphasize the setting in which the animals or plants live.
3. While the students are in discussion, post the enlargement of the place name map of the Colorado River Basin on a workable area of the wall or chalkboard. Pass out the 3x5 cards, scissors, 10 to 15 feet of yarn and masking tape.
4. When the discussion has finished, have each student choose one of the plants or animals they listed and write it on the 3x5 card. In groups, have the students post their animals and plants on the wall with the yarn connecting the cards and the locations on the map. If necessary help the students with key locations on the map.

> *NOTE: Some teachers prefer to use road maps as they are larger and contain much more information.*

5. Discuss the results. Emphasize the diversity of life forms. Have the students suggest life forms that were not posted but do live in the Colorado River Basin. List these and tape them to the wall near the posted cards.

> *NOTE: For younger students, this may be a place to conclude the activity.*

6. Ask each group to make a list of animals that are alive today but no longer live in the Colorado River Basin. For example, bison, wolf, grizzly bear etc. Discuss why they are no longer here.

7. Pass out three or four of the endangered or threatened species cards to each group. Ask the students to locate where each of these organisms live in or near the Colorado River Basin. Have them post the cards with yarn and tape. Some of the locations may be difficult to locate unless more detailed maps are consulted.

8. Summarize and review the richness of the wildlife that exists today. Point out that there are animals in recent history that have moved away from the habitat provided by the basin. Explore the factors that led to this disappearance. Compare the difference between animals moving to suitable habitat and those trapped in habitats that they cannot leave. The destruction of such habitats leads to extinction.

MORE

1. Discuss the meaning of the term *biodiversity*. Using the map and your lists of animals and plants, emphasize the interrelatedness of species.
2. Choose other river basins and repeat the activity.
3. Explore the worldwide threats to biodiversity.
4. Create a world map of endangered species.

CHECKING UP

1. List five endangered species in the Colorado River Basin.
2. List five things that humans are doing or could do to protect endangered and threatened species.
3. Describe five things that humans are doing that threaten other life forms.

SELECTED ENDANGERED OR THREATENED SPECIES IN THE SOUTHWEST

BLACK-FOOTED FERRET An animal once found everywhere prairie dogs were found. *ENDANGERED*	UTAH PRAIRIE DOG An animal found in a few locations in Garfield, Iron and Kane County, Utah. *THREATENED*
PEREGRINE FALCON AMERICAN and ARCTIC Birds that migrate throughout the basin. American is *ENDANGERED.* Arctic is *THREATENED.*	BALD EAGLE A bird found throughout the basin near open water in the winter. *ENDANGERED*
WHOOPING CRANE The largest of the cranes. A bird that migrates across the basin. *ENDANGERED*	VIRGIN RIVER CHUB A fish living in the Virgin River in Arizona, Nevada and Utah. *ENDANGERED*
WOUNDFIN A fish living in about 100 miles of rivers near Mesquite, Nevada. *ENDANGERED*	AUTUMN BUTTERCUP A small flower found on less than one acre of the upper Sevier River in Utah. *ENDANGERED*
CLAY PHACELIA A flower that lives in one location near Tucker, Utah. *ENDANGERED*	HELIOTROPE MILK VETCH A flower found in in the Manti-Lasal Forest, Utah. *THREATENED*
MAGUIRE PRIMROSE A flower that grows in the cracks of rocks in Logan Canyon, Utah. *THREATENED*	UNCOMPAHGRE FRITILLARY A butterfly found only in two sites above 13,000 feet in the San Juan Mountains, Colorado *PROPOSED AS ENDANGERED*

BIG BASIN BLUES

(GRADES 4-12)

WHAT WE WANT

Students will be able to evaluate issues concerning water use in the Colorado River Basin and other river systems.

HOW TO DO IT

Students do library and literature research to gather information regarding the health of several river systems and then make group presentations.

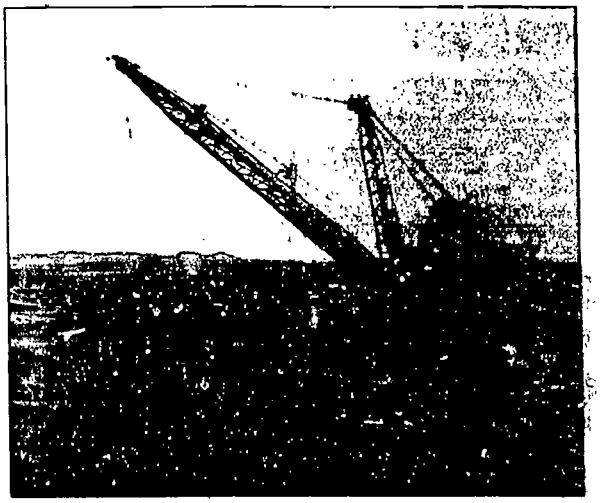
USEFUL INFORMATION

All of the river systems of the Earth are subjected to human use. Each river has its own unique set of conditions and shows different outcomes as a result of climate, ecosystem and human influences. For example, if we study the Colorado, Susquehanna, Ohio and Kissimmee we find four remarkably different ecosystems.

Each river ecosystem has a different set of conditions that characterizes its health. In the Ohio River Basin, precipitation amounts are remarkably different than in the Colorado River Basin. Rainfall amounts are much greater in the Ohio system and rain falls more evenly throughout the year. In the Colorado Basin, rainfall is often sporadic and subject to seasonal variations. Water use practices are also quite different for agricultural and industrial use in these two basins.

WHAT WE NEED

No specific materials needed; references such as encyclopedias, almanacs and other library-based sources are helpful as well as copies of teacher selected portions of the Background Materials contained in this teaching unit; access to some reference materials is essential.
(The background material included in this booklet provides an overview of the Colorado River system. Portions of it may be reproduced for students.)



STEPS TO SUCCESS

1. Have the students develop a familiarity with the Colorado River system through reading the materials provided in this unit or other sources available to them. Discuss some of the characteristics that make it a unique ecosystem. If at all possible arrange field trips to local points of interest. Stress the biodiversity of the region and how organisms are adapted to life within it. Look for situations, if any, where native species have been disturbed by human actions.

Primary Factors

Climate	- annual rainfall and temperature
Biodiversity	- common species - threatened and endangered species
Human use of the system	- domestic, industrial, recreational and agricultural use of the water
Geography	- the river and the landscape it passes through

2. Using the list of *Primary Factors* as a guide, describe the major characteristics of the Colorado River system.
3. Once familiarity with the Colorado River system has been achieved, have the students divide up into groups of three or four. Have each group choose a river system from elsewhere in the country (or world) that they will study.
4. When they are finished with their research, ask the students to prepare and make group presentations. These reports should be designed to provide insight into the unique conditions and problems facing each of the river systems. Each report should include all topics in the *Primary Factors* list above.
5. Once the presentations have been made, have all the students as a large group review the Colorado River system again. In discussion, strengthen the students' awareness of the similarities and differences shared by all the ecosystems.

MORE

1. Create a bulletin board display about each river system.
2. Study other major river systems in North America.
3. Locate the major dams on each river system that was studied and mark their location on a map.

CHECKING UP

1. Name at least four threatened or endangered species found in the Colorado River Basin.
2. Describe similarities and differences between two or more river basins.

PROS AND CONS

(GRADES K–12)

WHAT WE WANT

Students will be able to evaluate the consequences of human actions on specific features of the Colorado River system.

HOW TO DO IT

Students role play people who feel it is their right to uphold various lifestyles as they use the Colorado River system.

USEFUL INFORMATION

The Colorado River Basin is popular with people the world over as well as among the people who have lived there for generations. At one time, the number of people who lived in and visited the basin was well within the capacity of the ecosystem to remain healthy and viable. In recent times, the popularity of the basin has increased. Tourists from all over the world have discovered its immense beauty and serenity. In addition, widespread agriculture, industries, tourism, mining and the impact of additional people moving into the Basin have all contributed to changes that raise concerns about the ability of the system to survive.

All of the people who live in or come to the river system feel they have a right to do so. Often people do not see how their particular interests can injure an ecosystem—especially if they feel they act responsibly pursuing their chosen interest. Yet the signs of pressure are easy to find. Some of the specific problems are:

- overgrazing
- air and water pollution from mines and industry
- increased human population
- impact from hikers and visitors in certain ecosystems
- increased demands for water by agriculture, municipalities and industry
- pressure to build more dams for hydroelectric power
- habitat loss affecting rare and endangered species
- increased numbers of tourists and recreational use

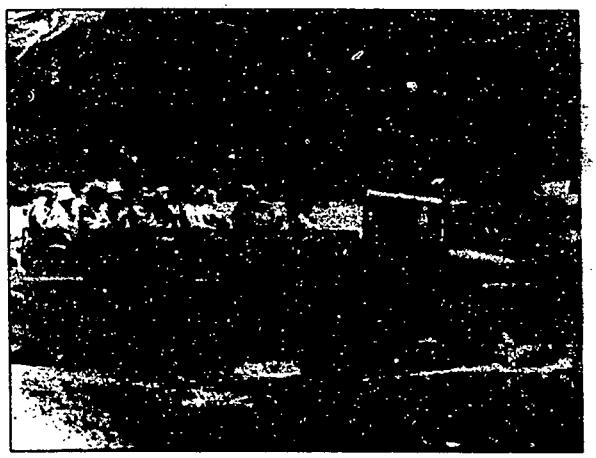
Role playing requires that students imagine themselves to be another person. They must imagine what the person might feel and think. They should speak and act like the person would. It is helpful to give young children the assigned role as homework. In this way they may be able to get help from parents in understanding the role.

WHAT WE NEED

Role play cards.
(The role play cards provide a short statement about a particular interest held by a resident or visitor to the Colorado River Basin. The cards must be copied and passed out by the teacher at the appropriate time with one card per student. Make additional cards if needed).

STEPS TO SUCCESS

1. Begin with a discussion in which the general appeal of the Colorado River Basin is explored. Ask the students what kinds of things they like to do in the Basin. Also ask them what they would like to try but have not yet been able to.
2. Pass out the role cards with one card per student. Ask each student to assume the role that is presented on the card. Even though the cards each have names suggested on them, invite the students to create a fictitious name for themselves that captures the spirit of the interests designated on the card. For example—a cyclist might be *Ima Tenspeed* or a fisher might be *Landa Trout*.
3. Have older students write a short position paper from the perspective of the person in the role described on the card. They should prepare to enter into a classroom debate to defend their right to do the things inherent in their role. Encourage younger students to go directly into the role.
4. To begin the role play, announce to the students that a special meeting of the *Colorado River Use Council* has been convened. Select a five person panel to hear the students present their arguments defending the role they represent. Each student will present arguments for his or her position specifically including the positive attributes of the role's perspective. The *Council* will then ask the entire group to react to each student's presentation. In particular the *Council* will seek to identify and discuss the negative impacts that activity might have on the Colorado River system. Following the presentation and discussion, ask the students to generate a list of the positives and negatives associated with each activity.
5. Next ask each student to reassess his or her role position. Ask students to consider how they would modify the activities associated with their role in order to reduce any negative impact on the Colorado River Basin. Repeat the presentation and discussion of the activities before the *Council* at the next class meeting.
6. Ask the students as a group to generate a list of recommendations concerning human activities in the Colorado River system. Discuss the recommendations.



MORE

1. Choose another river system in a different ecosystem and repeat this activity. See if there are differences in how the role affects you.
2. Meet with groups that are dedicated to a particular use that you favor. In what ways are they trying to be more responsible for the consequences of their activities? Are there other things they could do?

CHECKING UP

1. List uses of the Colorado River system in order of high impact to low impact on the long term health of the river's ecosystem.
2. Describe four high impact activities and four low impact activities.

PROS AND CONS ROLE CARDS

IMA TENSPEED I like road racing and endurance racing on paved roads. *Racing cyclist*	DEREK OFFROAD I ride dirt-bikes as far away from pavement as I can get. *Mountain bicyclist*
FREDA FLYFISHER I hate those clods that use bait and hardware especially in boats. *Dry fly fisher*	BUD BASSBOAT Show me quiet water, something to munch and hungry fish. *Bait and lure fisher*
CONCRETE PORTER We should have a dam in every canyon for power and water to sell. *Dam builder*	SARA SORGHUM Irrigation is my way of life. *Farmer*
HENRY HOLSTEIN I need grazing land, feedlots and a lot of cow feed. *Feedlot owner*	BOB BACKCOUNTRY It's the back country that calls me. *Wilderness trip leader*
WILMA WHITEWATER I like clear water, a raft and fast water "rollin on the river." *River rafter*	POPPER MAGNUM I still haven't found the old grand daddy elk but I'll die tryin'. *Hunter*
BUILDA GADGET I bring jobs and prosperity to any town. Growth is my middle name. *Manufacturer*	CLASSY FRAMER People need homes and I am the person that can build 'em. *Homebuilder*
CYRRUS CLOUDFLOATER Air commerce and recreation are who I am and flying is what I do. *Aviation developer*	WILLIE WILDWATCHER High power binoculars and a good field guide are all I need. *Wildlife watcher*

LEAP FIRST Skydiving every day is my motto. *Skydiver*	CLIFF SOARER Quiet wind and a high cliff. That's all I need. *Hang glider enthusiast*
ROCK CLINGER Lots of rope and iron and I can climb whatever you point to. *Rock climber*	RIVER BANKS Saving the life along the river is my passion. *Riparian preservationist*
EDIE ENDANGERED I am a biologist trying to save endangered fish in the Colorado River Basin. *Fish biologist*	PETE PETROGLYPH I am a cultural preservationist dedicated to protecting native works. *Native cultu. ? preservationist*
TRENDY TOURIST I want to find the real places to go. Those places where *no* one goes! *Tourist*	HI WATTS I want to increase the power output to meet people's wants. *Electric company manager*
HI OPENRANGE I need to have my cattle go where they want to, like in the good old days. *Rancher*	RIPARIAN PARKS Picnics and camping alongside the streams and the rivers is best. *Avid Camper*

WATER IN THE AIR

WHAT WE WANT

(GRADES K-6)

Students will be able to demonstrate that surface area affects evaporation and that water enters the air.

HOW TO DO IT

Students examine the relationship between the surface area of a body of water and the rate of evaporation by directly measuring the amount of water that evaporates from different containers.

USEFUL INFORMATION

Much of the water loss from naturally occurring bodies of water is through evaporation. Molecules of water move from streams, rivers, lakes and reservoirs directly into the air. Once in the air they are carried along until conditions are right for the water molecules to begin to condense. Often they condense around tiny particles of dust, pollen and many other microscopic objects. As condensation continues, the water molecules cluster together to form droplets. Eventually the droplets grow in size to full-sized drops and cluster together by the billions to form clouds. The clouds move into different conditions of temperature and pressure, the drops fall from the air in the form of rain. Sometimes the drops freeze and crystalize to form snow. Hail is formed when the freezing drops of rain fall and are swept upwards by powerful winds in the clouds. After they are swept upward and fall repeatedly the freezing hailstone gets bigger. Eventually the hailstone is too heavy to continue this up and down cycle and it falls to the ground.

Clouds transport the water that has evaporated long distances in the air. Scientists estimate that clouds carry millions of tons of water each day. Every day the clouds pass over lands where the conditions are rare for rain to fall. These are called arid lands. Arid lands are those that do not get much rainfall. As such, the little bit of water found in arid regions is particularly vital to all the people who live there. These people realize that water is one of the most valuable substances on Earth.

Yet even while recognizing its importance, many squander water at a remarkable rate. In the Colorado River Basin there is surprisingly little water. The waters of the region are primarily contained in river valleys with relatively fast moving water. Natural lakes are a rarity. In recent years the building of dams has increased the surface area of the water in the region by creating reservoirs that added hundreds of square miles of impounded waters. Immense amounts of water evaporates from these surfaces. It is estimated that 2,000,000 acre feet are lost from the Colorado River system each year to evaporation. One acre foot is 325,850 gallons.

WHAT WE NEED

One test tube and one petri dish per group; one graduated cylinder or an accurate measuring cup per group; pencils and paper.

STEPS TO SUCCESS

1. Divide the class into groups of three to five.
2. Discuss evaporation with the students. Ask if they have any proof that water gets into the air (evaporation) and stays there for a period of time (clouds). Explore their intuition about evaporation and how water can get into the air. If appropriate to the students' maturity, discuss the possible role of temperature in evaporation (warm air often carries more moisture than cool air).
3. Show the students the two drawings below:

The first is a cross section of a river flowing in the bottom of a deep canyon. The second is the cross section of a river blocked behind a dam. Have the students note the different width of the surfaces.

4. Tell them that they are about to conduct an experiment about evaporation.
5. Pass out the test tubes and the petri dishes.
6. Use the graduated cylinder or the measuring cup to put equal amounts of water in both the test tube and the petri dish. Accuracy is important.
7. Ask the students to place the containers side by side in different parts of the classroom. Help them choose places in which the containers will not be disturbed for two days.
8. After two days have passed, ask the students to carefully pour the water that remains in the test tube into the graduated cylinder or measuring cup that they used at the beginning of the experiment. Measure and record the amount of water that was left in the test tube. Repeat for the petri dish.
9. Determine whether or not the amount of surface area affected the amount of evaporation.
10. Discuss the results and their possible relationship to evaporation in the Colorado River Basin.

MORE

1. Describe the effect of temperature on the experiment.
2. If this were an experiment based on conditions found on the Colorado River, in which of these places would you predict that evaporation was the highest: Lake Powell or Cataract Canyon?
3. If you were having an "evaporation race" with other students, how could you create conditions to make evaporation occur very rapidly?

CHECKING UP

1. Describe the effect surface area has on the amount of water that evaporates.
2. Write a short story about the impact of evaporation on plants and animals in the Colorado River Basin.

CANYON COUNTRY ART

WHAT WE WANT

(GRADES K-12)

Students will be able to identify plants, animals and habitat conditions in their locale.

HOW TO DO IT

Students create art objects in the form of natural material collages, drawings and photographs. Each of these art forms characterizes a different plant community and habitat in the area the students visit in the field.

NOTE: It is always important to treat sites visited in the field with respect and care. It is important that the activities of the students not injure the site. If private land is visited it is important to get permission and clearly explain to the landowner the purpose of the trip.

USEFUL INFORMATION

Various habitat conditions are characterized by different plant communities. Plant communities are most often abundant enough that some discrete collection of parts of the plants does not damage the ecosystem. One of the ways that field biologists through hundreds of years have collected and identified plants is through art. Artists have regularly accompanied great expeditions and made meticulous drawings. Locate some sources in a library or through historical societies.

With the introduction of photography, invaluable records of various life forms were made possible. In addition to photographing the plants, animals and landscapes, historically important images of the native people who once were the only human inhabitants of the region were recorded by early photographers. Drawings and photographs both have come to be used in unusual ways in recent years. Many contemporary photographers have used the early efforts of their colleagues as a starting point for returning to the original picture sites and re-photographing the scenes. These paired photographs show vivid examples of the changes that have taken place. Recently a scientific researcher studying changes in the Colorado River Basin viewed early western movies in an effort to note the shifts in vegetation and habitat that have occurred since the movies were made in the 1950s and 1960s.

Art as a process and the objects it creates are integral ways to explore the world. Regardless of the medium through which it is expressed, art provides an engaging way for people to connect with their environment. Many artists begin by capturing the moods, nuances and emotional content of landscapes, plants and animals. Gradually they develop a sense of intimacy with their subjects. This intimacy provides great depth about those subjects both artistically and scientifically. Skills of observation are fundamental to both art and science. This activity nourishes students' appreciation of art and the environment.

WHAT WE NEED

Art materials; various colors of construction paper, drawing paper; pencils, sketching pens, pastels, watercolors; glue—rubber cement, glue sticks, contact cement; water containers; paint mixing pans; clip boards for each student; cameras and film. A set of local field identification guides for plants, birds, rocks, etc. is useful.

STEPS TO SUCCESS

1. Gather the materials and go to the chosen site chosen for the field study. The site should have a variety of plant communities and habitats. Streams and their riparian habitats are ideal. Set up a commons area where

the majority of the supplies will be kept for the students to return to as needed.

2. To get the students engaged, have each begin with a collage activity. This is literally a find, collect and paste kind of effort. Invite them to spread out and pick a small area where they can be moderately alone and separate from other students. Be sure that the area that is chosen has enough variety so that the students can choose clearly different plants. Ask them to sit quietly in the area. Have them look around from where they sit and select several plants that they feel characterize the area. Do not permit excursions into small canyons without supervision.
3. Invite the students to collect characteristic pieces of the most common plants. Ask the students to avoid seriously damaging the plants. After collecting the plants, return to the supplies area and glue the pieces of plants to a sheet of construction paper. Have them create an aesthetic presentation of their plants.
4. Next gather the students together to discuss the similarities and differences among the plants collected. Encourage the students to describe and identify the area of the environment from which they collected their plants.
5. Select several of the art forms which are composed of different plants. Have each student whose art was selected lead the others to where the plant was collected. In each place identify some of the plants by name if possible. If identification is difficult then give the plant a metaphoric name that will help track it for later identification. Emphasize the relationships between the plant communities and their location in the overall habitat.
6. Return to the commons area and have the students choose another medium (charcoal, pastel, ink etc.) to record some of the specific characteristics of their site. Ask the students to make a highly detailed rendering of a small object on their site. For example, this may be a pebble, a pine cone, or a bird-feather. Set a time limit of about 15 minutes for them to complete the task.
7. Once the detailed art form is created, ask the students to use the same medium to attempt to capture the essence of the whole area that was visited. Have them be attentive to the "big picture." Allow another 15 minutes for this effort.
8. Once you have returned to the classroom, display the big picture efforts high on the wall with the various detailed efforts physically below them. Invite the students to discuss the relationships between the detailed art forms and what is portrayed in the "big picture."
9. Have the students attempt to identify the various plants in their art forms using the field books. Ask them to attach labels with the plant names on their art works. If they cannot identify the plant ask them to use the metaphoric name they made up in the field.
10. Through discussion, review and elaborate the overall nature of the visit. Stress plant communities and their location within the habitat. Emphasize how, by collecting many small pictures, we can begin to grasp the big picture.

MORE

1. Locate and examine some of the efforts of early artists and photographers who accompanied expeditions.
2. Try to find old photographs of the same area that you visited and see if you can document evidence for the changes that were found.
3. Explore the site that you visited for litter and trash. Compose a "collage of impact" from the litter to be exhibited with the other works.
4. Set up other field trips that provide a more complete portrait of the larger ecosystem in which we live.
5. Explore the art of other cultures that live in the basin.

CHECKING UP

1. Draw a composite portrait of the site and indicate the variety of life forms found there.
2. Identify four "wet habitat" plants and four "dry habitat" plants.

COUNTING WATER

WHAT WE WANT

(GRADES 5-12)

Students will be able to analyze and compare water uses within the Colorado River Basin.

HOW TO DO IT

Students find out how much water they use each day. Then they determine how much they personally use in a year. They compare that figure with what their own community uses in terms of the total population. Finally they approximate how much water the city and county of Los Angeles use from the Colorado River Basin during a year.

NOTE—An acre foot is the volume of water that will cover 1 acre (a square about 200 feet on each side) to a depth of one foot. It is roughly the size of a football field. It represents 325,850 gallons, more than the amount of water an average family of five uses each year.

USEFUL INFORMATION

In an agreement made in 1922 by the Colorado River Compact the river basin was divided into an upper and lower basin. Seven states were part of that division. The dividing line goes roughly northwest from Gallup, New Mexico, across the site of the Glen Canyon Dam near Page, Arizona, to a point in southwestern Utah. The members of the compact allocated 7.5 million acre feet of water to each basin totaling 15 million acre feet annually. In addition, a treaty made during World War II agreed to give 1.5 million acre feet to Mexico.

The combination of these agreements committed a total of 16.5 million acre feet of the Colorado River Basin's water for various uses—domestic, agricultural and industrial. An invisible consumer of water is the amount that is lost each year to evaporation from the river itself. Nearly all of this evaporation comes from reservoirs that are found behind the dams in the system. Two million acre feet a year are lost in this fashion. This means that 18.5 million acre feet are used by people and lost to evaporation.

The problem is that from 1930 to the present, the total volume of water flowing through the Colorado River Basin has averaged 14 million acre feet annually. This means that if 16.5 million acre feet are allotted and 2 million are lost to evaporation then only an average of 14 million is coming into the basin. *This means the river cannot deliver the amount of water that is expected.*

Millions of years have passed to establish the dynamic balance represented by the Colorado River Basin ecosystem. This long process produced the vast ecosystem that now stretches from the 14,000 foot peaks of Colorado's Continental Divide to the Sea of Cortez. During this time *all* of the basin's flowing rivers were devoted to sustaining the web of life that lived in and above their waters. Severe changes have taken place in the past hundred years. Twenty five million humans have become major water users and their needs far exceed the amounts used by other life forms. The impacts are substantial and may not be sustainable over time.

Million Acre Feet Annually	
Upper Basin	7.5
Lower Basin	7.5
Mexico	1.5
Evaporation	2.0
	18.5

WHAT WE NEED

Forms to record the necessary personal use information; calculators.

STEPS TO SUCCESS

1. Discuss water use and ways to measure and document an individual's personal consumption. Ask the students to determine how much water they consume in a day and a week. Extrapolate this use into an annual figure per person to establish the amount that each student uses in a year. If more accuracy seems appropriate, have the students calculate the water use for a week before converting to an annual figure.

FACT SHEET FOR CALCULATIONS

According to the *Cousteau Almanac*, domestic personal use is about 160 gallons per day per person.

Here is the breakdown;

3-5 gallons	flushing a toilet
5 gal/minute	showering
8 gallons	cooking
8 gallons	cleaning house
10 gallons	washing dishes
20-30 gallons	washing clothes
30-40 gallons	taking a bath
30-40	washing a car
30-60	watering a lawn

DOMESTIC USE — 160 gallons a day per person.

Water is also used to grow the food we eat and manufacture the goods we possess. A true calculation of water use must include the water that we use indirectly through conducting these activities. The average use of water for industrial and agricultural use is calculated to be:

INDUSTRIAL USE	1040 gallons/day
AGRICULTURAL USE	600 gallons/day
DOMESTIC PERSONAL USE	160 gallons/day
TOTAL USE PER PERSON	1800 gallons/day

2. On the basis of your town's or city's population, calculate the amount of water your community uses in a year. That is, find out how many people there are in your community and multiply that number by the average amount of water used by an individual per category of use.
3. Find out the population of Los Angeles (15,000,000 in the metropolitan area). By the same process estimate daily, weekly and annual water use in Los Angeles. Remember to remind the students to include commercial and agricultural use in their calculations.
4. Find out what restrictions apply to water users in large metropolitan areas. (Denver, Salt Lake City and Los Angeles may be helpful examples.) Information can usually be obtained by writing or calling the Department of Water Resources in city government offices. Libraries often have telephone books of major cities.
5. Discuss ways to conserve and protect water.

MORE

1. Find ways to reduce the use of water in your community. Examples are: practice conservation measures, landscape yards, parks, schoolgrounds, etc. with local, native plants and shrubs.
   Note: Native plants do not usually require watering above rainfall amounts.
2. If you do not live in the Colorado River drainage, calculate the water consumption for the river systems closest to your location.
3. Determine which industries in your community use the most water.
4. Create a water use conservation program for the school and put it into effect. Emphasize the use of water saving devices, drip irrigation practices, grey water use, constructed wetlands, etc.
5. Find the percentage of water in the Colorado River system that is allotted for use out of the basin and the percentage used in the basin.

CHECKING UP

1. Identify the major domestic uses of water in your household. Demonstrate that you can personally lower the use.
2. Demonstrate that you have reduced your water use in one month. Calculate the savings for a month.
3. Calculate the amount of water use savings in your community. Assume that everyone in the population conserved as much as you did personally.

Cousteau, Jacques - Yves. *The Cousteau Almanac*. Garden City, New York: Dolphin Books, Doubleday & Company, 1981.

ANCIENT WATERS

WHAT WE WANT

(GRADES 3-12)

Students will be able to illustrate conditions in the Colorado River system before modern times.

HOW TO DO IT

Through the use of simulated field trips students explore a portion of the history of the early Colorado River Basin.

NOTE: The texts of the simulated field trips are written for students in grades 4 and above. Teachers using this activity with younger children may choose to simplify the words.

USEFUL INFORMATION

In the rocks alongside the rivers of the Colorado River Basin, stone layers are found that provide evidence of some of the earliest forms of life on Earth. Long before the dinosaurs, small creatures of the sea thrived on the bottom of warm sunlit waters. One of the most complete records of ancient life is found in this part of the world. One set of fossils that is particularly important to us includes the remains of fish that were the ancient ancestors of many similar fish in the rivers of today. These were found in rocks that are 4,000,000 years old.

The first human visitors to this land appeared about 10,000 years ago and their livelihood was provided by hunting and gathering. About 6,000 years ago some of these wanderers began to settle and establish semi-permanent camps. Eventually, about 1,500 years ago, stone dwellings of ancient complex civilizations appeared throughout the Colorado River and its tributaries.

These ruins indicate that humans and the river lived side by side for centuries long before Europeans settled in North America. These early people depended on the river's waters. Carvings in the rock surfaces, called petroglyphs, show us that many of the plants and animals we find today were common in the past.

For nearly 500 years, European explorers and settlers traveled across the surface of this region seeking cities of gold, routes to the Pacific, and, for some, homesites where they would try to wrest a living from the land. It was these early visitors who brought technologies that seemed innocent enough at first, but would change the face of the land forever. An extraordinary industrial era began. With it came established trails, wagon trains and eventually the railroad. Railroads opened up the wild lands of the west, increasing the effects of humans on the land. Permanent roads and bridges were built and, for many, nothing stood in the way of their gaining a livelihood except for the limited availability of water in the region.

WHAT WE NEED

Assorted art materials; text for the simulated field trips; time line.

STEPS TO SUCCESS

1. Ask the students to put their pencils, pens and notebooks aside. Invite them to make themselves comfortable, relax and, if they choose, to close their eyes. Explain that you are going to read them the first of several narratives. Tell them that they are going on a simulated field trip to the Colorado River Basin.
2. Read Part I of the text.
3. Ask the students to open their eyes and make a drawing or painting of what they saw on their simulated field trip.
4. Once their artistic expressions are finished, invite the students to describe the scenes they portrayed. Have them emphasize the Ancient Waters theme. Display the art work in the classroom in a way that leaves room for the efforts of Part II and Part III to be displayed as well.
5. Next read Part II. Tell the students that this time their simulated field trip will take them to early human involvement with ancient waters in the Colorado River Basin.
6. Repeat steps 3 and 4 from above. Emphasize the importance of water to each of these groups of ancient people. Talk about similarities and differences between each group and their interaction with water.
7. After displaying and discussing the art, tell the students that you are going to present them with Part III of the Ancient Waters story. This simulated field trip will be quite different from the others since the story takes place *beneath* the surface of the Ancient Waters.
8. Ask the students to discuss their reaction to the three simulated field trips.
9. With the students' help create a time line on the chalkboard that ties these events together. Use the following information as an approximate reference.
10. Assemble large sheets of art paper or use rolls of butcher type craft paper. Ask the students to work together to create a mural that portrays the whole sweep of the three simulated field trips. Students may want to incorporate their earlier drawings into the mural.
11. As a final step in this activity, ask the students to write a summary statement or summarize aloud the legacy of the Colorado River Basin over time.

MORE

1. Identify and learn about the endangered species that live closest to your home or school.
2. Expand the time line to include some other early species and events in Earth history (origin of the Earth, giant sharks, dinosaurs, ice ages, etc.).
3. Discuss the future of the basin based on the decisions people are making today.

SUCCESS

1. Create a chronology of changes in the Colorado River Basin.
2. Describe major events in basin history and their significance to people, wildlife and the environment.

TIME LINE (APPROXIMATE)

12 feet	4,000,000 years ago	ancestors of today's fish
3 feet	1,000,000 years ago	fish similar to today
1/3 inch	10,000 years ago	early hunters
1/5 inch	6,000 years ago	early settlements
1/50 inch	500 years ago	Europeans in new world

TEXT FOR ANCIENT WATERS
Part I

Long before humans walked the Earth, ancient waters flowed in the channels of rivers and streams. These waterways carved landscapes in much the same fashion as do rivers today. Great lakes and inland seas became temporary resting places for the flowing waters. Once in the lakes or seas, the waters evaporated and drifted upward in massive clouds. Winds carried the clouds back over the lands again. From high in the air the conditions became right for the water to fall to the Earth—and the cycle began again. For millions of years these patterns were repeated and the great cycle of water would drain and replenish the clouds, rivers and oceans.

Cycles were not only found in the waters. Sometimes forces within the Earth itself caused mountains to bulge upward and the solid rock would shatter and break. Other places the earth bent downward and made deep troughs where oceans or seas could collect. Life forms flourished in the oceans and the seas. The rivers changed, the oceans changed and so too did all the life on the planet. Some of the early life forms were embedded in soft sediments when they died. The sediments in turn were transformed into rock and the animals' bodies became fossils. These fossils tell much of the story of ancient waters. If you looked around you could see fragile looking fan-like corals and sharks larger than any in today's oceans. On the land, great forests emerged. Dragonflies a foot across and sturdy amphibians and reptiles began to appear. And then came the dinosaurs. They were the most physically imposing life forms of all for millions of years. Eventually small rat-like mammals became common. Later in time, the much larger mammals appeared. Mastodons and huge bisons became common. This was the time of the saber-tooth tiger. Fish abounded in the rivers and birds filled the sky.

Close your eyes for a moment and try to look closely at a scene that shows what these ancient lands and ancient waters were like. In a moment I will ask you to use some art materials to draw or paint what you see.

TEXT OF ANCIENT WATERS
Part II

About 10,000 years ago a time-traveling visitor would have seen people wandering about the Colorado River Basin searching for food, water, shelter and the space needed to live their lives.

They learned to hunt and collect foods growing in the wild. They did not have houses nor could they build dwellings at all. Huge mammoths, bison and smaller horse-like animals were hunted for food. Sometimes the stronger runners of the clans would chase bison across mesas and drive them off high cliffs where the shaggy creatures would fall to their death. The clan would then gather and feast on bison meat and turn the hides into clothing and other useful things. After a very long time changes in the climate affected the size of the herds of animals. The people had difficult times.

About 6,000 years ago people in the Colorado River Basin began to settle in temporary camps where they built primitive dwellings. The buildings were sleeping circles, huts and windbreaks. The people were skilled at gathering different kinds of food—so skilled that they began to build food storage structures where they put the extra food. They moved along with the seasons. They looked for different roots, tubers and fruits.

About 2,000 years ago, the people of the Colorado River Basin realized that some of the seeds they collected as they traveled could be planted to make gardens. Farming and agriculture were born. The ancient water now became a basic need, not just for drinking, but as a necessity for agriculture. Since plants need water to grow, the wanderers chose to stay where water was easily found. Villages became more permanent. The life of the settler began to dominate. The life of the wanderer had begun to disappear. This was 500 years before Europeans would land in the new world.

Close your eyes for a moment and create a scene in the life of each of these ancient people—the hunter, the gatherer/hunter and the planter. Then select some of the art materials and create your version of an event in the life of each of these groups of people. Emphasize the environment and how people lived.

ANCIENT WATERS
Part III

You are deep in a pool in the Colorado River. The water is cool but not unpleasant. This is not the Colorado River of today. This is the Colorado River of 4,000,000 years ago. Many kinds of different fish are swimming around you. Some are small—just a few inches in length. Others are many feet long. All are flourishing.

Now let us take a leap forward in time. We are under the river's surface and it is 10,000 years ago. This is during the same time period in which the ancient people were driving bison off cliffs to their death. This was long before any settlements, long before farming—and yet most of the same fish that we saw in these waters 4,000,000 years ago are still swimming about. They live throughout the entire span of the Colorado River system. They move freely up and down the river to select breeding grounds. Millions of thunderstorms have flooded the channel, whole mountain ranges of silt have washed down the river, uncountable generations of these fish have been born, lived and died. These species of fish have lived in the Colorado River drainage for millions of years. It is likely that the ancient people who lived in the Colorado River Basin sometimes ate these fish. Even so, the fish were plentiful and they persisted into the present.

Today most of these fish seem doomed. In the waters of the Colorado River Basin, four of these fish species are listed as endangered. This means they could be near extinction. Extinct means gone forever. As the remaining fish swim in the river, it is clear that this is not the same river of their ancestors. As these species try to survive, they are confronted with threatening kinds of pollution from many different sources. Farming, mining and other kinds of industry are contributing unfavorable substances to the river. Hundreds of new communities have been built on the river's shores. Yet the greatest hazard these fish species face are the dams. The dams change the amount of silt in the river and the temperature of the waters. They also create barriers to the breeding and spawning sites.

Today the waters of the Colorado River are home for very small populations of the original species of fish that have lived there for 4,000,000 years. The native fish of the Colorado are disappearing fast. It is likely that some may vanish in our lifetime.

Review all three parts of the Ancient Waters story. We will discuss your conclusions and then I will ask you to paint a mural that represents the feelings of the entire class.

INVISIBLE PASSENGERS

(GRADES 3-12)

WHAT WE WANT

Students will be able to identify and describe a variety of natural and introduced materials that are found in river waters.

HOW TO DO IT

By using several different jars containing water and different substances, the students observe and describe the behavior and effects of silt, sand, gravel, salt and odor sources.

USEFUL INFORMATION

For millions of years the Colorado River system has been eroding the arid landscapes that make up its basin. Uncounted tons of materials have washed downstream in the past millions of years. Many of these materials like sand, silt, salt and gravel occur naturally. Other substances are pollutants that have come from human activity. Oil, sewage and chemical fertilizers are examples. There are naturally occurring pollutants that are washed into the streams and rivers. Several varieties of salt found in rock formations is an example. Natural sources of lead, gypsum and compounds of calcium are also found in different places in the basin.

Human caused pollution generally come from activities that concentrate pollutants that sometimes occur in nature. Mining, agriculture, manufacturing and sewage treatment are examples of activities that concentrate often harmful substances. Scientists have learned to fashion tests to see if introduced substances—whether naturally occurring or not--are found in water.

Sometimes storms create local high water conditions. This raises the water level and often increases the speed of flow. Such conditions can cause water to flush areas on the river banks that are not normally in contact with the water. This dumps silt and clay minerals into the water and the rivers temporarily become cloudy and muddy. Increased water flow also scours the river bottoms and banks. Sand and gravel may be moved downstream if the force of the moving water is great enough.

It is clear that if materials are being carried in the water all the forms of life using that water are subject to the effects of these substances. Silt provides an unfavorable environment for certain plants and fish. Other organisms thrive in its presence. Some substances are toxic and even water temperature has an effect on certain species. Certain fish seek out specific "odors" to find their way back to spawning grounds so some naturally occurring materials actually benefit their survival.

WHAT WE NEED

Twenty jars with secure lids (quart size); sand; clay (silt); gravel (pebbles of different sizes); a one pound container of household salt. If at all possible, try to collect the sand, clay and gravel locally. You will need about one bucket of each material.

NOTE—Ahead of time, prepare five jars, half filled with water, to which a single odor substance has been added. Vinegar, vanilla extract, household ammonia, bleach and perfume are examples. Number the jars for use in step 9.

STEPS TO SUCCESS

1. Divide the class into five groups. Distribute four jars to each group. Remind the students to use caution as the jars are breakable.
2. Have the students fill each of the four jars half full of water. Add a cup of sand to the first jar, a cup of silt or clay in the second jar, and a cup of gravel to the third. In the final jar add 1/3 cup of each—sand, silt and gravel.
3. Ask the students to observe the behavior of the materials as they settle naturally. Ask them to record their results. Discuss the differences that are observed.
4. Advise the students to make sure the lids are tightly fastened on the jars. Then ask them to shake all the jars vigorously for a moment or two. Have them set the jars on the desks at the same time. Which settles the fastest? Which settles the slowest? Which is easiest to stir up after it settles?
5. Invite the students to determine how to show each of the following:
   -flood time or rapid flow behavior of the water (rapid motion)
   -low water or slow flow (gentle or no motion)
6. Discuss what behavior you have when rapid flow is followed by slow flow in each jar (silt seldom settles).
7. Try to see if anything changes by adding a teaspoon of salt to the mixtures in each jar. The salt dissolves and creates little or no visible effect. Yet it is an "invisible passenger." Discuss where the salt might come from in nature (natural minerals in stream beds and agricultural practices of irrigation cor entrate salt in soil).
8. Ask the students if they think they have a good sense of smell. Invite them to see if they can detect a difference in the odor of the different mixtures of sand, silt, gravel and the mixture of all three. Discuss their efforts. Invite them to describe the odors they detected.
9. Tell the students that biologists believe that many fish use their senses of "smell" in different ways. Some use sensitivity to "odors" for feeding and migrating to spawning habitats. Tell the students that they are going to see how many odors they can accurately detect in water. Ask them to write the numbers 1-5 on a piece of paper.
10. Pass out one of the prepared and numbered jars to each group. Ask them to open them carefully and pass the jar to everyone in their group. They are to record the jar number and the odor or "passenger in the water" they think they detect. Once the jar has been passed among all the members of the group, trade the jar with another group. Repeat until all the jars have been sampled by all the students in the class and the lists are complete.
11. Discuss the possible effects of each of these conditions on living things in the rivers. Point out that there are remarkably different characteristics in the natural habitat provided by rivers. Emphasize that there are changes in these habitats that take place day to day as well as seasonally. The natural living inhabitants of these environments tend to have adapted to these changes. However when new conditions are imposed on the rivers (such as from the effects of agriculture, mining and dams), the native inhabitants are often negatively impacted. Some are imperiled to the point of extinction.

MORE

1. Make a model of a dam crossing a river and relate what you learned about the behavior of different substances in the water to conditions you could expect to find around different parts of the dam.
2. Look at rivers in your own community and see if you can determine where the substances in these waters are coming from.
3. Explore the role of water, sand, silt and gravel in the formation of the Grand Canyon.
4. Invite a local water resource person to test the quality of the water students bring from home or collect in nature.

CHECKING UP

1. List several substances found in river water.
2. Describe how fish use "odors" in the water.
3. Identify several basic components of sedimentary material (sand, silt and gravel).

HABITAT HAZARDS

WHAT WE WANT

(GRADES 3-12)

Students will be able to identify specific endangered fishes and indicate their present geographic locations.

HOW TO DO IT

Students create a model of the Colorado River system and use it to indicate the primary location of various endangered fishes.

USEFUL INFORMATION

The razorback sucker, Colorado squawfish, bonytail and humpback chub are fishes that were abundant virtually everywhere in the Colorado River Basin a hundred years ago. The favored habitat of each of these endangered fish is now far more limited. Their very existence is at risk. Fisheries specialists are conducting research and managing resources in efforts to insure their survival.

The ENDANGERED FISH INFORMATION CARDS are located at the end of this activity. they contain a general description of the conditions that support these creatures.

Since these species are on the edge of extinction, they are considered indicators of environmental conditions. They are reference points as we explore the various conditions that have affected their ecosystem. Basic to the study of ecosystems is the premise that all parts ar connected—and important—to all other parts. Changes in one place ultimately affect other places. For a species to become endangered, there have to be significant changes in the conditions that support their livelihood.

Within an ecosystem each species has its *niche.* A niche is how an organism "makes its living" — how it eats, reproduces, grows and contributes to the whole of the living ecosystem in which it is found. Taken together, the collection of niches in any ecosystem describes a larger system. This ecosystem describes a larger system. This means that the limits of a description of any ecosystem is arbitrary. The entire Earth can be viewed as a *single ecosystem.*

In recent years biologists and ecologists have emphasized the importance of seeing the world as a whole. There has even been a new term to frame their emerging interest—*biodiversity.* Biodiversity is an index of diversity and variety of living things in an ecosystem.

WHAT WE NEED

Glue or tape; heavy mounting boards for base map; several pounds of plasticene clay (oil based clay); toothpicks; two different colors of yarn (about two feet each).

NOTE: 1. Find the relief map in the appendix. Make a same-size copy of the map and cut the copy into four equal pieces as indicated by lines. Enlarge each of the 1/4 page segments to a full 8 1/2 x 11 page. Fasten the four segments together to make a single large map. Attach the enlarged map to a base. You will need four of these enlarged maps for the class.

2. Make four copies of the Colorado River Basin place name map and give one to each of the four groups.

3. Make one copy of each of the four information sheets for the endangered fish. Provide one sheet to each of the four groups. Each group will have a different fish sheet.

STEPS TO SUCCESS

1. Divide the class into four groups (depending on class size this could be six to nine students in each group). Pass out the following:
   a. The four sections of the base map
   b. One map containing the place names in the Colorado River Basin
2. Ask the students to use tape or glue and fasten the enlarged map to a piece of plywood, heavy cardboard or some other kind of support.
3. Invite the students to use the place name map as a reference and mark the *rivers only* using a wide marker.
4. Instruct the students to turn the flat map into a relief model by applying the clay to the areas between the rivers. It is important to emphasize that this is an approximation of the landscape. Encourage them to be as accurate as possible but point out that absolute accuracy is very difficult with these materials. Have them leave the human-made features out of the construction until later.
5. As the base map gets covered with the clay, conduct "pop" quizzes on the river names and other salient natural features. When the model is finished the students should have a general awareness of the "highlands," river channels and the route from mountains to ocean. Have them use the place name map as a reference to help them locate places on the emerging model.
6. Once the model becomes complete, pass out one of the endangered fish information cards to each of the four groups. These cards have the following:
   a. A drawing of the fish
   b. A figure showing past and present distribution of the fish
   c. A brief general description of the fish

   Ask the students to choose a representative to read aloud the name of their fish species and the description on the card. Emphasize the places in the rivers where the fish lived in the past and where they are found today.
7. Ask the students to use one color of yarn to show the original range of each of the fish described on the card. Use a second color to show the range today. Discuss the differences in the range in the past and at the present for each of the four fish species.
8. Ask the students to use the place name map and locate the major dams in the basin. Find and show where the dams are on the models. Discuss the location of the dams and the range of the endangered fish.
9. Ask the students to add the location of the major communities in the basin. Discuss the relationships between human activities and the range occupied by the fish. Discuss reasons for and against building dams.
10. Ask the students to analyze and summarize what they have learned from this activity.

MORE

1. Using the model as a base, locate the sites of your visits with places in the basin. Describe to the rest of the class your reactions to the places you have visited.
2. Show some of the historical trips made by early explorers to the region. If possible read selections from their journals. (State historical societies and libraries are a good source for such materials.)

CHECKING UP

1. Locate the dams on the Colorado River system.
2. Locate the range of the four major endangered fish.

APPENDICES

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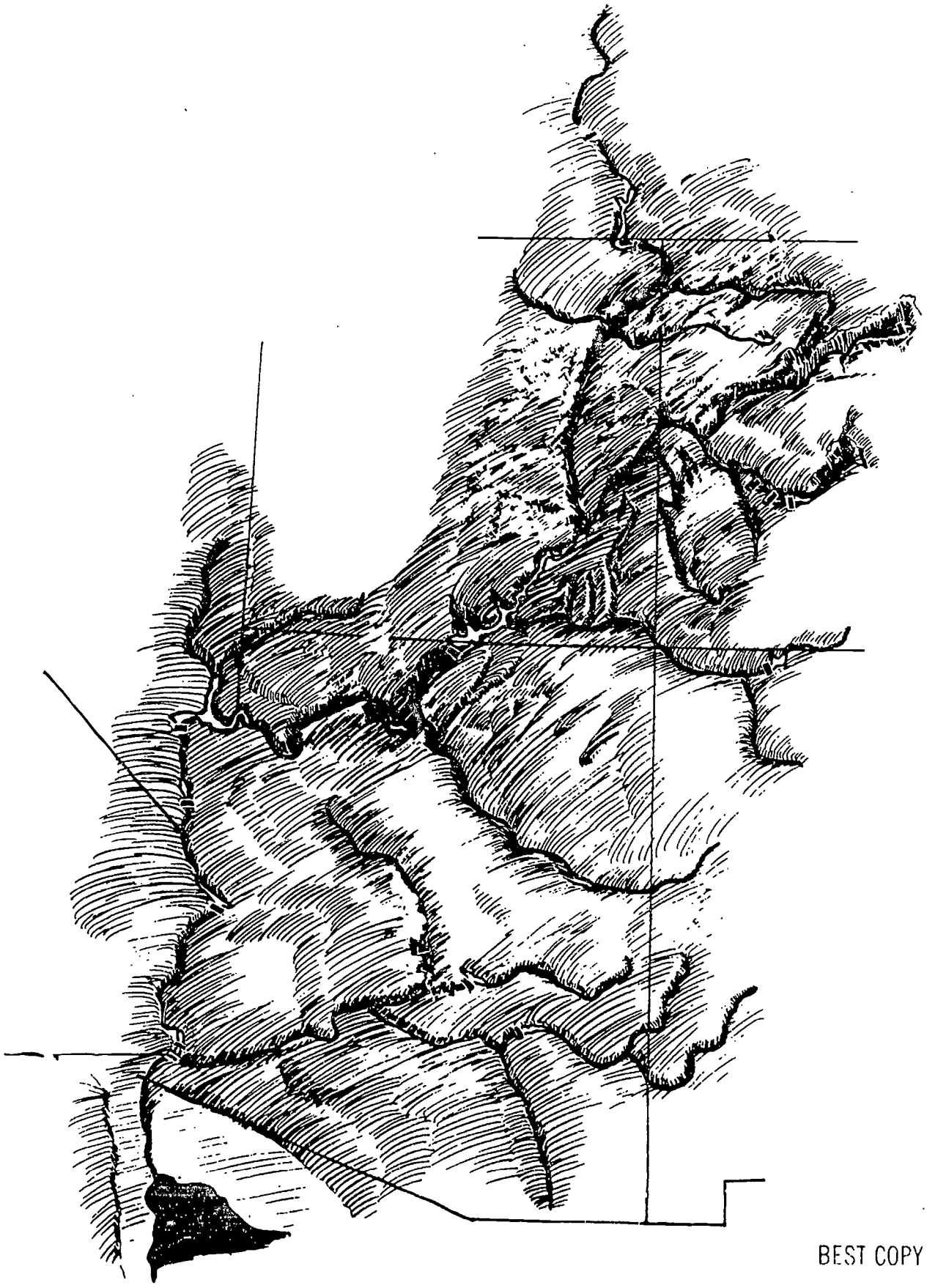

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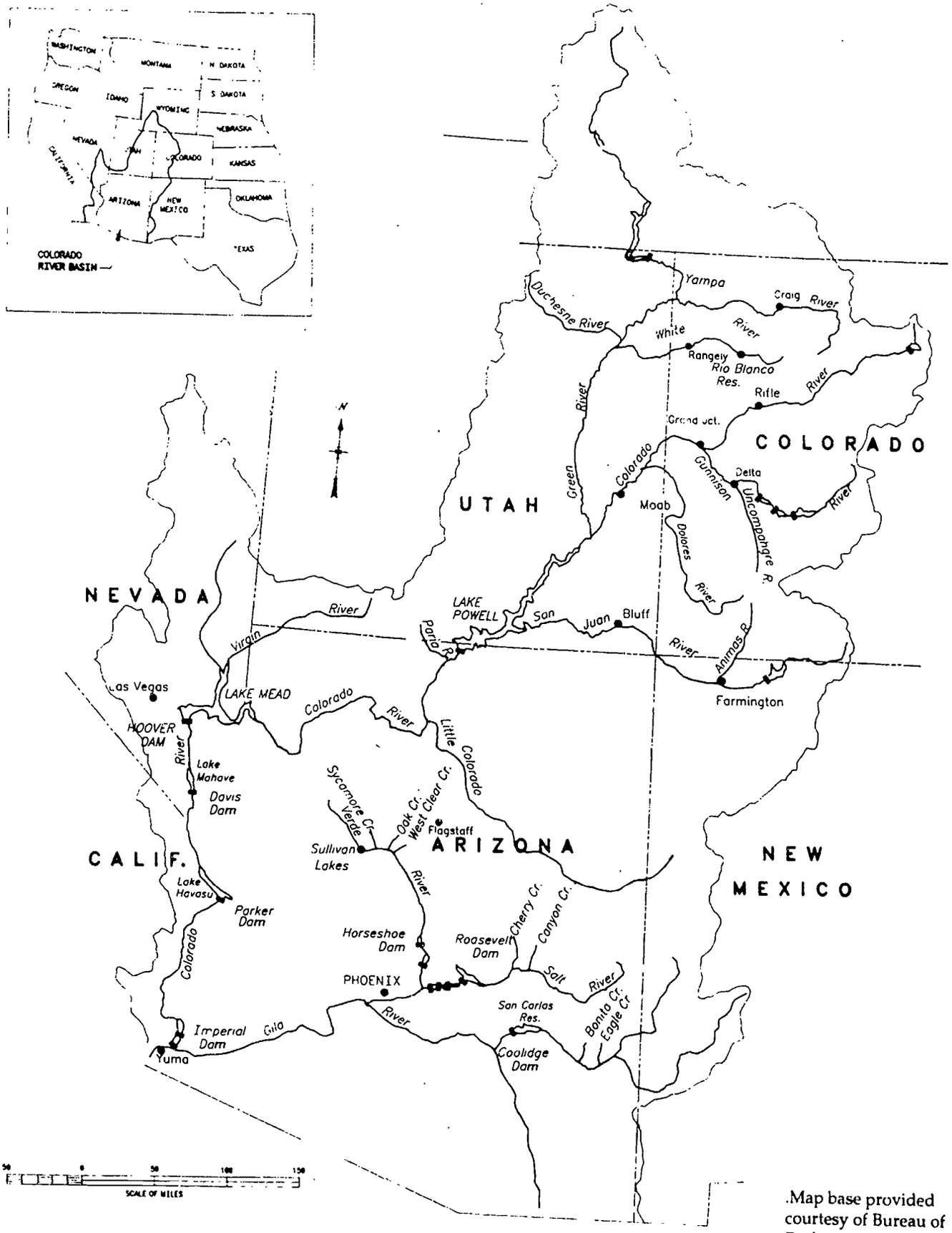

COLORADO RIVER BASIN

.Map base provided courtesy of Bureau of Reclamation, United States Department of the Interior.

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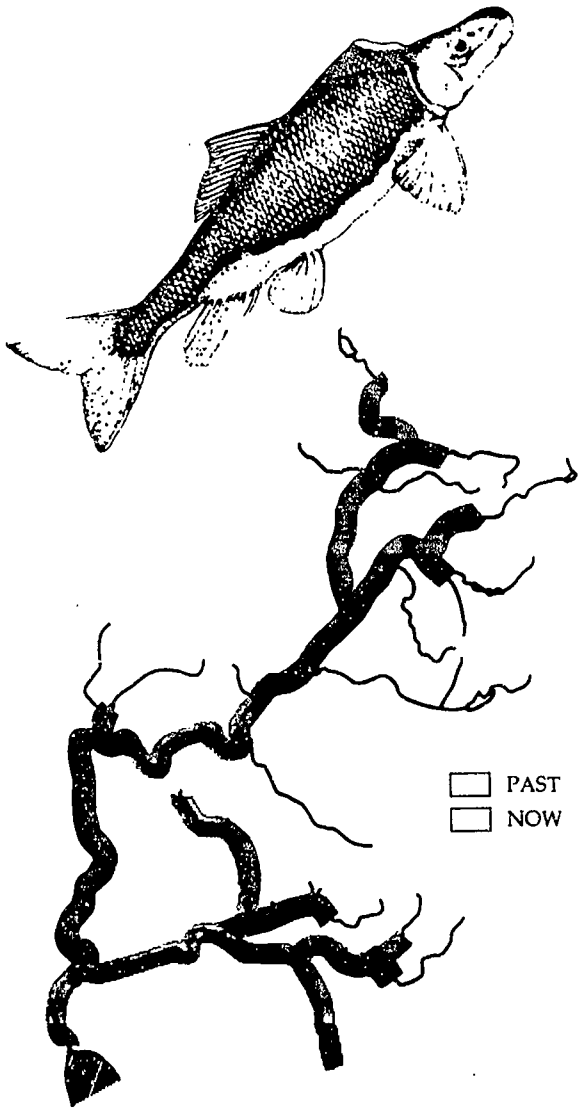
Razorback Sucker

This fish once ranged the Colorado River drainage from Wyoming to Mexico. It has a large bony ridge down its back and a bulbous sucker mouth. As recently as 1949, they were caught and sold for food in Arizona. They sometimes reached a length of three feet and weighed 13 pounds. In most locations there are only large, mature fish. Young and juveniles are mostly absent. Biologists suggest that the absence of these smaller razorbacks may be due to predation by other fish and the loss of rearing habitat. This species lives in slow moving water and tolerates water temperatures that vary from 10 C (50 F) to a high of 30 C (86 F). Adult razorbacks spawn in areas where the river bottom is composed of gravel and pebbles. Newly-hatched razorbacks seek protection in gravel among cobble-sized pebbles. When larger, they move to flooded bottomlands. Their primary diet is invertebrates, plankton, algae and decaying plant material.



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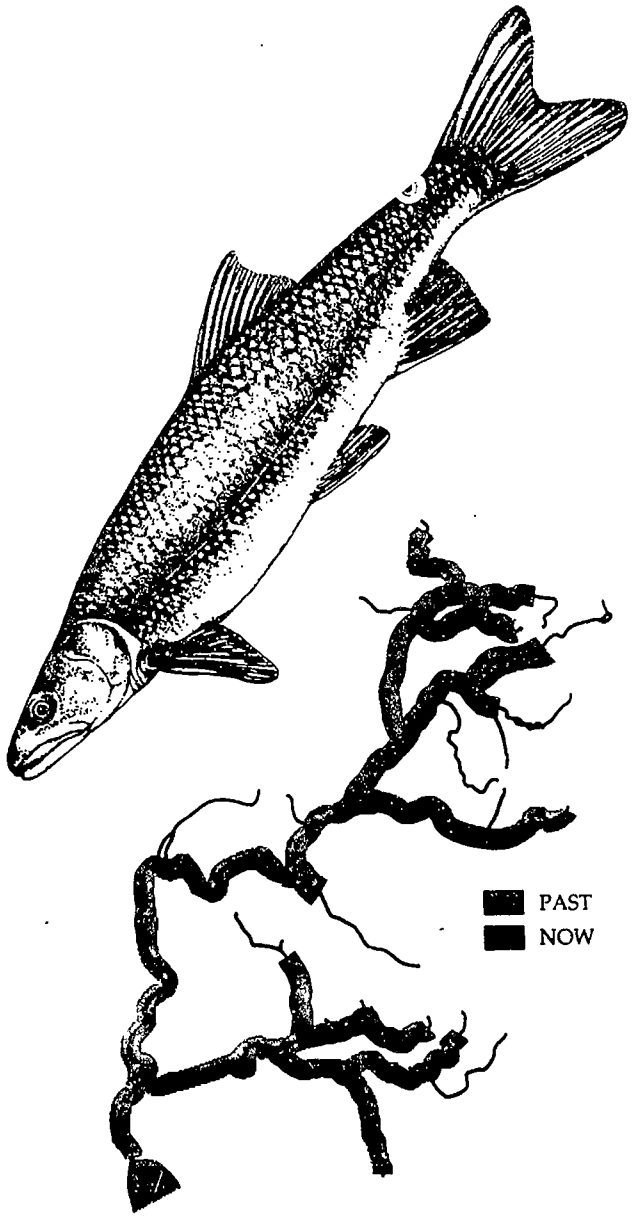

Colorado Squawfish

The Colorado squawfish was once found throughout most of the Colorado River drainage from Wyoming to Mexico. It is the largest member of the minnow family found in the United States. It can reach a length of five feet and weigh 80 pounds. Currently, the squawfish occupies less than half of the system's rivers. This fish has adapted to river water that is turbulent, sometimes filled with silt, and seasonally changes velocity. Squawfish tolerate water temperatures that range from 10 C (50 F) to 35 C (95 F) and spawn in water that is as warm as 21 C (70 F). They also migrate up to 200 miles to specific spawning areas for reasons not yet understood. This tendency to migrate long distances earned them the somewhat misleading title *Colorado River salmon*. Their favored foods are zooplankton and insect larvae when they are young and other fish as they mature.

Drawings: copyright Marianne C. Filbert

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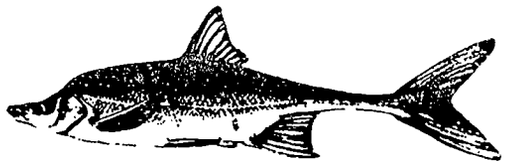
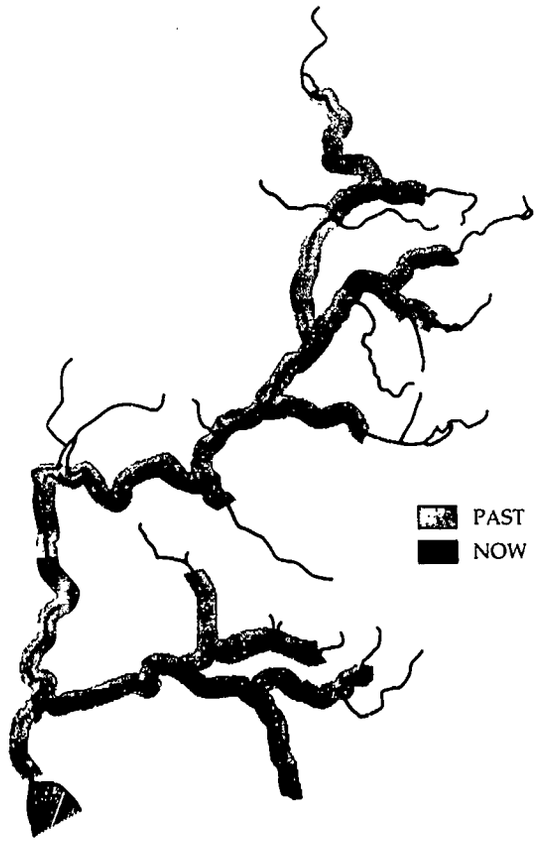
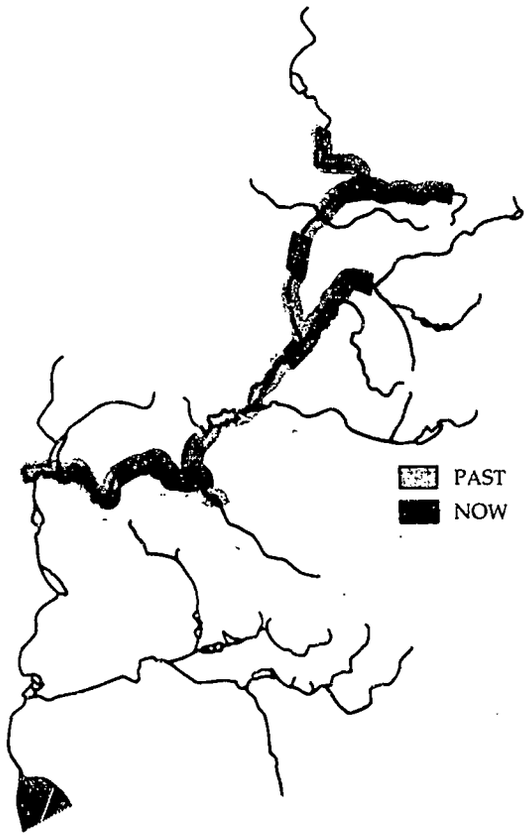
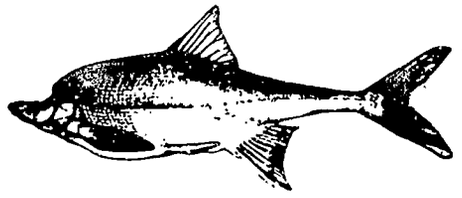
Bonytail

This fish, like the others, once occupied a much wider range in the Colorado River Basin than it does at present. In recent years, only a few specimens have been found and some biologists think it is extinct above Lake Powell. Its present habitat is restricted to six isolated patches of the rivers of the Colorado River system. Mature fish can be as large as two feet in length. The bonytail prefers pools and eddies at the edge of swift currents. In reservoirs the fish prefer sandy or gravelly bottoms. Some evidence suggests they prefer these conditions for spawning as well. Bonytail eggs hatch most successfully in waters that range between 15 C (59F) to 20 C (68F). The young chubs eat larvae and nymphs. As the fish mature, they shift to feeding on larger insects, gastropods and caddis flies.









Humpback Chub

The humpback chub is found in a small percentage of its original habitat. It reaches a length of 18 inches and is named for the fleshy hump behind its head. This fish occurs in all types of river habitat—fast water, eddies, deep pools and around large boulders at the base of steep cliffs. Young humpbacks prefer quiet shorelines and still backwaters. Adults spawn in water temperatures from 11.5 C (53 F) to 23 C (73 F). Their diet consists largely of planktonic crustaceans found along river bottoms, however this species has been seen eating certain insects on the waters' surface.

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